

REVISITING THE OPEN CLUSTER M35

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Abstract. We present a study of different properties of the young open cluster M35, including very deep and accurate photometry, rotational and radial velocities, and lithium abundances.

1. Previous studies of the cluster.

M35 is a young, rich open cluster. During the last years, different authors have studied its properties in detail. Sung & Bessell (1999) have derived a distance modulus of $(m-M)_0=9.60\pm0.10$, a reddening of $E(B-V)=0.255\pm0.024$ and an age of $\tau=200^{+200}_{-100}$ Myr. Sarrazine et al. (2000) have obtained $(m-M)=10.16\pm0.01$, $E(B-V)=0.198\pm0.008$ and $\tau=160\pm40$ Myr. On the other hand, proper motions for stars warmer than late F spectral type have been measured by McNamara & Sekiguchi (1985) and the total dynamical mass has been evaluated as 1600–3200 M_\odot (Leonard & Merritt 1989). Prior to our study, about 1100 candidate members were identified, down to $V\leq19.5$ mag.

2. A new vision of M35.

We have carried out several observing runs, both photometric $-V(RI)_C$ filters– and spectroscopic ($R\sim20,000$), with several goals:

(i) By using color-magnitude diagrams, we have identified new low mass candidate members of the cluster, down to $I_C=23.5$ mag, including 65 brown dwarf candidates and another ~1700 stellar candidate members. The photometry comes from KPNO 4m telescope and Canadian-France-Hawaii telescope. Figure 1 shows one of our color-magnitude diagrams.

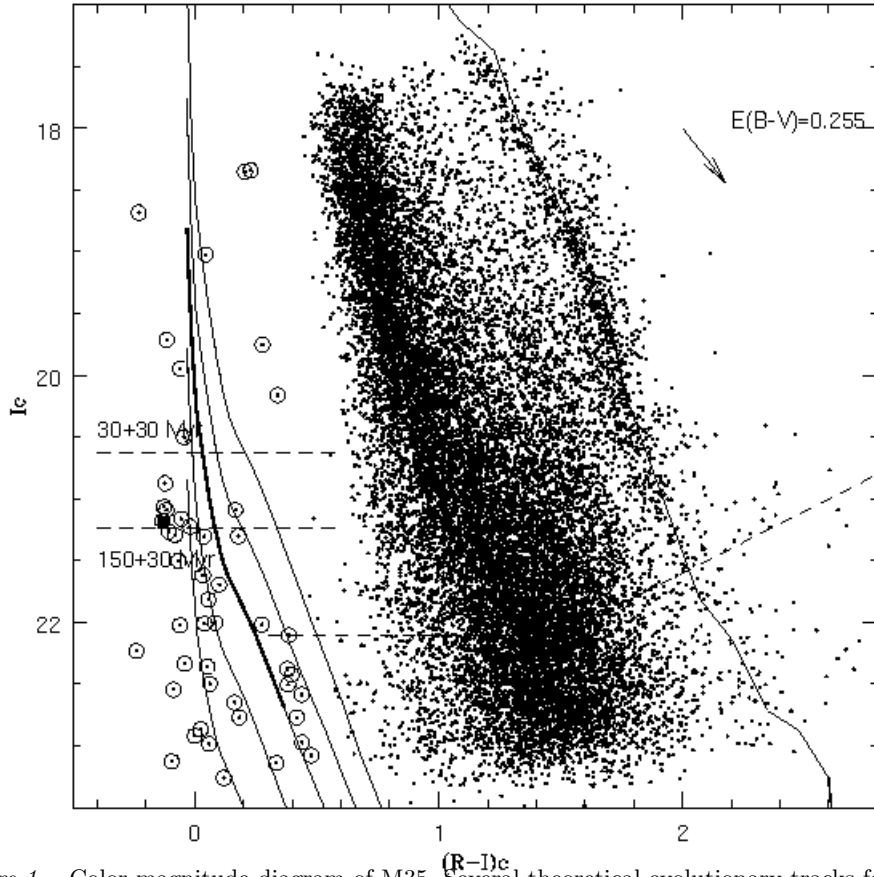


Figure 1. Color-magnitude diagram of M35. Several theoretical evolutionary tracks for WD are included.

(ii) The new extended population of tentative members of the cluster has been used to derive an accurate Luminosity Function and Mass Function (MF) for the total stellar population of the clusters ($6-0.08 M_{\odot}$). Figure 2a depicts the MF and a comparison with the Pleiades (80–100 Myr, data from Hambly et al. 1999) and field stars (Gould et al. 1997). The main characteristics of the M35 MF are its accuracy (due to its richness) and the three different indices α depending on the mass range (see the figure). These discontinuities in the MF could indicate that there were several mechanisms working when the initial cloud fragmented and collapsed. In addition, we have estimated the total mass of the core of the cluster, $1600 M_{\odot}$.

(iii) We have identified a population of white dwarfs (WD). The LF of WD and the comparison with theoretical isochrones suggest that the cluster is 180 Myr (see Figure 1).

(iv) The high resolution multi-fiber spectroscopy (WIYN/HYDRA) for 76 photometric candidate members were used to select a population of *bona*

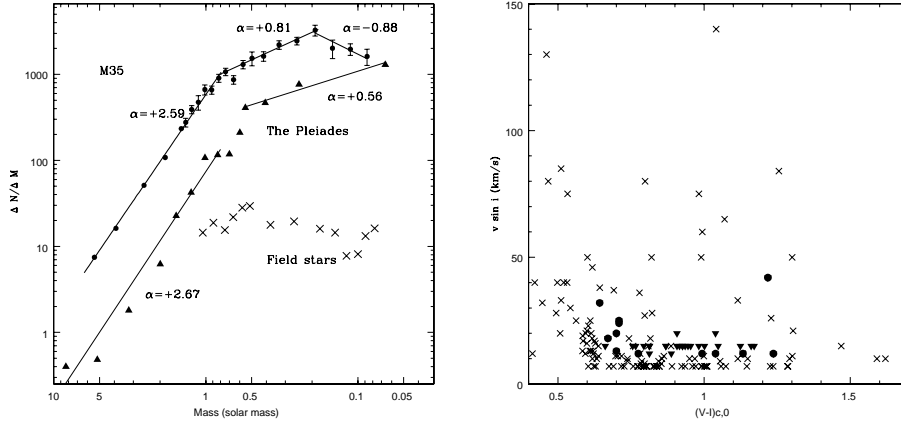


Figure 2. **a** Complete Mass Function for the stellar population of M35 (solid circles). We have included a comparison with the Pleiades (solid triangles) and field stars (crosses). **b** Rotational velocity distribution for M35 stars (solid symbols) Pleiades data are displayed as crosses.

fide members (39 stars of late F, G and early K spectral types). Another 13 objects present variable radial velocities in a two days time span. (Three are SB2 binaries.) We consider them as possible members of the cluster.

(v) Cross-correlation techniques were used to derive rotational velocities for these 76 stars. The distribution of $v \sin i$ versus the $(V-I)_C$ color index is shown in Figure 2b (solid triangles -upper limits- and circles). M35 lacks fast rotators in this color range, in opposition to what happens in the Pleiades (crosses). This distribution confirms that M35 is older than the Pleiades.

(vi) Our free spectral range (6440–6850 Å) contains a dozen iron lines. We have derived the metal content for the brightest stars in the sample using spectral synthesis and model atmospheres (Kurucz 1992). The M35 metallicity is $[\text{Fe}/\text{H}] = -0.21 \pm 0.10$, whereas the Pleiades value is $+0.01$ using the same procedure.

(vii) We have measured lithium 6707.8 Å equivalent widths. Lithium abundances were derived using curves of growth (Soderblom et al. 1993). Figure 3 displays the M35 lithium abundances versus effective temperatures (solid symbols), together with a comparison with Pleiades stars (crosses). Clearly, the lithium spread present in the Pleiades (Butler et al. 1987; Soderblom et al. 1993) does not appear in M35. For a given temperature, M35 abundances tend to be smaller. Our high quality M35 database of lithium abundances and rotational velocities is perfectly suited to be used as a laboratory to test theoretical models dealing with the lithium depletion phenomenon.

Additional details can be found in Barrado y Navascués et al. (1999)

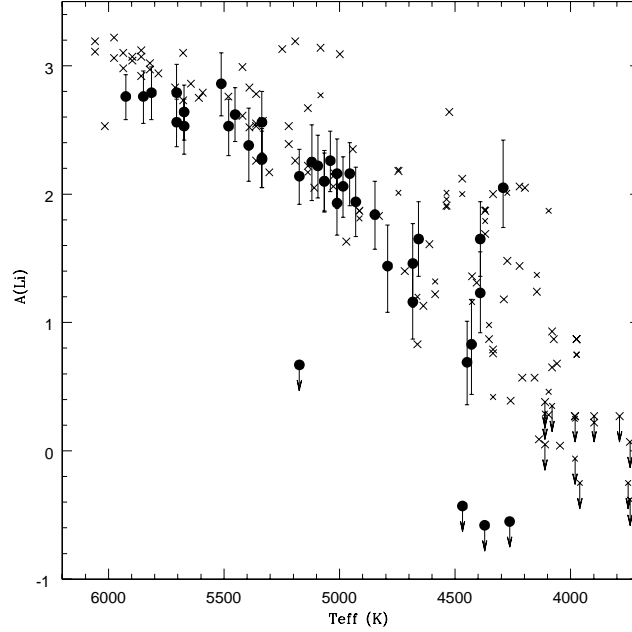


Figure 3. The effective temperature – lithium abundance plane. M35 members are shown as solid symbols, whereas Pleiades stars appear as crosses.

and Barrado y Navascués et al. (2000a,b).

Acknowledgements

This work has been partially supported by Spanish “*Plan Nacional del Espacio*”, under grant ESP98-1339-CO2.

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